MULTIFOCAL INTRAOCULAR LENS

BACKGROUND OF THE INVENTION

The present invention relates to a multifocal intraocular lens for implantation in the human eye having a plurality of concentrically-arranged regions alternately powered for differing vision ranges, e.g., near and far vision, surrounding a substantially circular central region.

Various lenses have been disclosed which have a circular central region surrounded by a single ring. For example, U.S. Pat. No. 3,420,006 discloses bifocal contact lenses in which a central region powered for distance vision is surrounded by a ring powered for near vision, while U.S. Pat. No. 3,270,007 discloses the reverse configuration. U.S. Pat. Nos. 3,726,587 and 4,636,049 also disclose bifocal contact lenses in which a central region powered for near vision is surrounded by a ring powered for far vision. These latter lenses are said to work better than earlier lenses having the near-vision portion outside the distance portion.

U.S. Pat. No. 4,573,775 discloses soft multifocal contact lenses having a vertical array decreasing power. U.S. Pat. No. 4,580,882 discloses a contact lens in which the power varies continuously outward from a central area for distance vision.

U.S. Pat. No. 4,636,211 discloses bifocal intraocular lenses having a central region powered for near vision and a single surrounding ring powered for distance vision.

Each of these earlier disclosures offers some optical theory as to the reason for operation of a particular lens design, and U.S. Pat. Nos. 3,726,387, 4,636,049 and 4,636,211 specify particular preferred sizes for the near and far vision portions. Such size specifications represent a compromise, however, in order to provide adequate light collecting area in both the far and near vision segments if significant pupillary excursion occurs under different lighting conditions. This compromise is necessary if the known lenses are to provide both distance and near vision at both extremes of high and low lighting levels and thus small and large pupillary aperature, but leads to decreased efficiency of near vision at low lighting levels (assuming a near-vision central portion) and decreased efficiency for far vision at high light levels. The claimed invention overcomes this difficulty, thus providing bifocal intraocular lenses which more closely approximate the vision range of a natural lens.

SUMMARY OF THE INVENTION

According to the invention, multifocal lenses are formed having a substantially circular central region having a first optical power, surrounded by a plurality of concentric ring regions which alternate between at least two optical powers, one of which may be the first optical power. Thus, the concentric ring regions begin with an innermost ring region having a power different from the power of the central region, and progress outward with each successive ring region having a power different from the power of the immediately inward ring region, with the proviso either that a least one of the ring regions has the same power as the central region, or that at least two of the ring regions have the same power. Preferably, the central region is powered for near vision. For example, one embodiment of the invention is a bifocal lens having a central near-vision portion, a first concentric ring region powered for distance vision, and a second concentric ring region having the same power as the central region.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a sectional view of a human eye with the intraocular multifocal lens implanted in the anterior chamber.

FIG. **2** shows a sectional view of a human eye with the intraocular lens implanted in the posterior chamber.

FIG. **3** shows a sectional view of a human eye with an intraocular multifocal lens permanently fixed on the cornea beneath the epithelium.

FIG. **4** shows a sectional view of a human eye with an intraocular multifocal lens permanently fixed in the cornea in the stroma layer.

FIG. **5** shows a sectional view of a human eye with an intraocular multifocal lens permanently fixed in a pocket in the cornea between the epithelium and endothelium.

FIG. **6** is a plan view of an intraocular bifocal lens according to the invention.

FIG. **7** shows a sectional view of the intraocular lens having a plano-convex shape.

FIG. **8** is a sectional view of the intraocular multifocal lens having a bi-convex shape.

FIG. **9** shows a convex-plano-convex lens.

FIG. **10** shows a convex-concave intraocular lens.

DETAILED DESCRIPTION OF THE INVENTION

Intraocular lenses are surgically implanted lenses used as a replacement for, or in some cases as an adjunct to the natural lens. For example, after a cataract or clear lens extraction operation in which the natural lens is removed, an intraocular lens may be implanted in either the anterior chamber **8** or the posterior chamber **12** of the human eye **10** as shown in FIGS. **1** and **2** respectively. In either case, the lens may be affixed in place using any of a wide variety of haptic designs which are well known in the art.

Intraocular lenses may also be implanted by corneal-inlay techniques, i.e., they may be surgically placed in various positions in or on the cornea **7**. FIGS. **3–5** exemplify these various positions within the cornea; i.e., just below the epithelial layer (FIG. **3**), within the stroma layer (FIG. **4**), and within the cornea in a surgically created pocket (FIG. **5**). The intraocular lens according to the invention may advantageously be utilized in any of these environments.

FIG. **6** shows one embodiment of a bifocal intraocular lens according to the invention. This lens **1** has a substantially circular central region **22**, a first concentric ring region **24** coaxially surrounding the central region **22**, and three more concentric ring regions **26, 28** and **30** coaxially surrounding the first concentric ring region **24**. If the central region **22** is powered for near vision, then concentric ring regions **24** and **28** are powered for far vision, while concentric ring regions **26** and **30** are powered for near vision. In this way, an alternating pattern of near-far-near-far-near is obtained in the central and ring regions of the lens. In other embodiments of the invention, fewer or more concentric ring regions might be used. In addition, rings having additional powers may be incorporated in an alternating fashion to give a multifocal lens. In a multifocal lens, the concentric ring segments may be an alternating array of regions of two or more powers all of which are different